Montana Department of ENVIRONMENTAL QUALITY

MEMO

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To: TBD

CC: Eric Urban, Water Quality Standards Section Supervisor

From: Michael Suplee, Ph.D., Water Quality Standards Section, Montana Department of Environmental Quality

Date: 9/27/2016

RE: Water Quality Standards in Circular DEQ-12A for Flathead Lake

Draft Circular DEQ-12A, which is part of the proposed numeric nitrogen and phosphorus standards rules in MAR notice No. 17-356, contains water quality standards for Flathead Lake. It is the only lake for which the Department is proposing standards at this time. The purpose of this memo is to outline the social, legal, technical, and scientific rationales for the proposed lake standards.

1. Background on the Development of the Proposed Standards

In the early 1990s a 'Flathead TMDL Team' (supported by the Flathead Basin Commission) initiated a series of meetings in the Flathead Lake area. The team's goal was to derive water quality targets and develop the Total Maximum Daily Load (TMDL) for the lake. As of 1995, the team comprised seventeen members from eleven different government and private organizations (**Appendix A**), representing a wide array of interests and points of view. The Flathead Basin Commission was routinely apprised of the team's work (and also provided a member to the team). By 1995 the team had identified provisional targets (to be measured at the Midlake Deep monitoring site[1]) based on the conditions that existed in the lake between 1977 and the early 1990s (**Table 1**). By the late 1990s, the team completed its review and released a somewhat different

[1] Located about 1 mile west of Yellow Bay Point at approximately 47.861 latitude, -114.067 longitude.

group of final targets, again, most of which are assessed at the Midlake Deep site (**Table 1**). The team's work was made public and the Flathead Basin Commission received a number of comments on the final targets.

Table 1. Flathead TMDL Team Water Quality Recommendations for Flathead Lake and the Proposed Water Quality Standards in Circular DEQ-12A.

Water Quality Parameter	Provisional Recommendations of the Flathead TMDL Team (1995)	Final Recommendations of the Flathead TMDL Team (1998)	Proposed Standards in Circular DEQ-12A (2014)
Total phosphorus (TP)(µg/L)	5.5	5.0	5.0
Total nitrogen (TN)(µg/L)	98	95	95
Phytoplankton chlorophyll *a* (µg/L)	1.01	1.0	1.0
Secchi depth (meters)	10.8	n/a	10.4
Primary productivity (g C/m^2/year)	n/a	70[a]	n/a
Soluble reactive phosphorus (µg/L)	n/a	<0.5	n/a
Nitrate plus nitrite (as N)(µg/L)	n/a	30.0	n/a
Ammonia, as N (µg/L)	n/a	<1.0	n/a
Dissolved oxygen in hypolimnion	n/a	No declining trends	n/a
Algae blooms	n/a	No measurable blooms	n/a
Algal biomass on near-shore rocks	n/a	Stable or declining trend, measured as Chl*a* /m^2	n/a

[a]The Flathead Basin Commission later raised this value to 80 g C/m^2/yr because it was considered interim and could be adjusted later if other targets were not being met.

An important aspect of the Flathead TMDL Team's work was that the targets were developed based on their best understanding of the lake's existing high-quality condition. This is consistent with the Flathead Basin Commission's mission to "protect the existing high quality of the Flathead Lake aquatic environment…" The Flathead Basin Commission was created by the MT Legislature in 1983 (§75-7-302, MCA). Therefore, the water quality that existed around the mid-1980s is the condition to be maintained, which aligns well with the Flathead TMDL Team's approach to target development. It should also be noted that the lake is classified A-1, meaning it is afforded the highest level of water quality protection the state provides short of a drinking-water supply. Because of (1) the amount of work already invested in developing the targets, (2) the legislatively-defined mission of the Flathead Basin Commission, and (3) the high level of water protection (class A-1) afforded the lake, the Department believes the level of water quality appropriate for the lake is well defined and, further, the targets have been well vetted (via stakeholder input, public meetings, and comment) in the Flathead Lake area. As a result, the Department requested initiation of rulemaking for the lake standards at the January 22nd, 2014 Board of Environmental Review meeting.

2. Technical and Scientific Review of the Proposed Standards

Readers will note that the proposed standards in Circular DEQ-12A for Flathead Lake are not the same as the targets provided by the Flathead TMDL team in 1998 (**Table 1**); this requires some explanation[2]. From the Department's perspective, water quality standards must protect a beneficial use (or uses), and a linkage between water quality standards and a beneficial use is essential. Both phytoplankton chlorophyll *a* (Chl*a*) and Secchi depth link directly to water clarity and, in turn, to the recreation beneficial use. (The recreation use for A-1 waterbodies is codified in ARM 17.30.622.) The Department did not propose the soluble nutrients for adoption because in most northern temperate lakes the relationship between total nutrient concentrations and phytoplankton Chl*a* is reasonably tight, therefore the total nutrient standards should provide adequate protection. Nitrogen is not always proposed for lake standards, but Flathead Lake has been shown to be nitrogen and phosphorus co-limited (Dodds et al., 1989) and therefore the inclusion of total nitrogen (TN) is necessary. The location where the proposed standards will be measured (at Midlake Deep, where extensive water quality records exist), and the means by which they will be assessed (as annual averages) will provide long-term constancy in the assessment of standards attainment. The Department did not propose primary productivity (PP) standards for three reasons: (1) its linkage to beneficial use impact is somewhat complex, and therefore less clear than for Chl*a* and Secchi depth, (2) in an oligotrophic lake like Flathead Lake PP may vary by ±20% due to climatic influences (Finger et al., 2013), making standards setting more difficult, and (3) the Department is not currently equipped to measure and monitor PP if the need were to arise. Even without PP, the Department believes the four parameters proposed in Circular DEQ-12A will achieve the basic goal of maintaining the lake's high-quality water.

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[2] The Secchi depth in Circular DEQ-12A was developed in cooperation with the Flathead Lake Biological Station between 2012 and 2013, and reflects their most accurate estimation of the appropriate value based on long-term data. It is only slightly different from the 1995 recommendation of the Flathead TMDL Team.

The set of proposed standards in Circular DEQ-12A are identical to what was first recommended by the Flathead TMDL Team back in 1995, and the values are nearly the same (**Table 1**). To cross-check the proposed standard's validity, I calculated the phytoplankton Chl*a* concentration that would result from the proposed nutrient standards using well-known relationships in the scientific literature (**Table 2**). These models have direct application to northern temperate lakes. Four commonly-cited models that predict

Table 2. Published Models used to Evaluate the Proposed Water Quality Standards for Flathead Lake. The first four models only use total P as an input to calculate phytoplankton Chl*a* . Smith (1982) is a mutiple regression equation using TP and TN. Carlson TSI values are each based on one of the four proposed standards.

Published Model	Input Variable	Output (Result)	Result Average
Dillon and Rigler (1974)	5 µg TP/L	0.75 µg Chla/L	1.45 µg Chla/L
Jones and Backmann (1976)	5 µg TP/L	0.85 µg Chla/L	
Rast and Lee (1978)	5 µg TP/L	1.87 µg Chla/L	
Barsch and Gakstatter (1978)	5 µg TP/L	2.34 µg Chla/L	
Smith (1982)	5 µg TP/L and 95 µg TN/L	1.05 µg Chla/L	n/a
Carlson (1977) *Trophic State Index (TSI)*	5 µg TP/L	TSI = 27.4	TSI of 26.2
Carlson (1977) *Trophic State Index (TSI)*	95 µg TN/L	TSI = 20.5	
Carlson (1977) *Trophic State Index (TSI)*	Phytoplankton, 1.0 µg Chl*a* /L	TSI = 30.6	
Carlson (1977) *Trophic State Index (TSI)*	Secchi depth of 10.4 m	TSI = 26.3	

phytoplankton Chl*a* using lake TP concentration provided an average of 1.45 µg Chl*a*/L (range: 0.75 to 2.34), reasonably close to the proposed standard of 1.0 µg Chl*a*/L. (These four model all assume P limitation.) Using the TP plus TN equation of Smith (1982), the proposed nutrient standards (5 µg TP/L and 95 µg TN/L) equate to 1.05 µg Chl*a*/L, nearly identical to the proposed standard. The Smith (1982) has particularly good application to Flathead Lake because the lake has been shown to be N and P co-limited.

I then calculated the Carlson Trophic State Index (TSI; Carlson, 1977) using all four proposed standards (**Table 2**). The TSI was developed after extensive study of the contamination and subsequent cleanup of Lake Washington, and is widely used to assess lakes across the northern United States. The proposed standards yield an average TSI of 26.2 (range: 20.5 to 30.6). The TSI levels associated with Flathead Lake's proposed standards are therefore within the TSI range (20-30) of a classically-defined oligotrophic lake, i.e., a lake with clear water, oxygen throughout the year, and salmonid fisheries (Wetzel, 1983; EPA, 1988; MPCA, 2004).

I used the phosphorus (P) loading model of Vollenweider (1975) to evaluate the proposed standards from another angle. The model can be used to evaluate a lake's vulnerability to move from one trophic state to another, depending on the P load to the lake and the lake's mean depth and flushing rate (and assuming

P limitation). Faster flushing lakes are generally less susceptible to eutrophication than lakes with long residence times (Vollenweider, 1975). Flathead Lake has a flushing rate of about 3 years, a mean depth of about 48 m, and an average P load of approximately 130 metric tons/yr (DEQ Bathymetric Data; Stanford et al., 1997[3]). Results are in **Figure 1**. Flathead Lake's flushing rate normalized to mean depth (H/τw; abscissa of **Figure 1**), at 16 m/yr, is not particularly fast or slow (fast rates are on the right hand side of the abscissa, slow rates on the left). The lake's average annual areal P load is about 0.26 g P/m^2/yr. Note that Flathead Lake lies on the oligotrophic-mesotrophic boundary (lower curved line in **Figure 1**). This shows that Flathead Lake, from a P-loading point of view, would not require a large increase in annual P load to move into mesotrophy (an event which, based on earlier discussion, should be prevented). This analysis supports the idea that the TP standard should be maintained as proposed, because a higher P concentration would allow increased P loading to the lake and, based on **Figure 1,** a likely move into mesotrophy. Co-limitation with N will, to some degree, mitigate the degree of movement into mesotrophy caused by an increased P load.

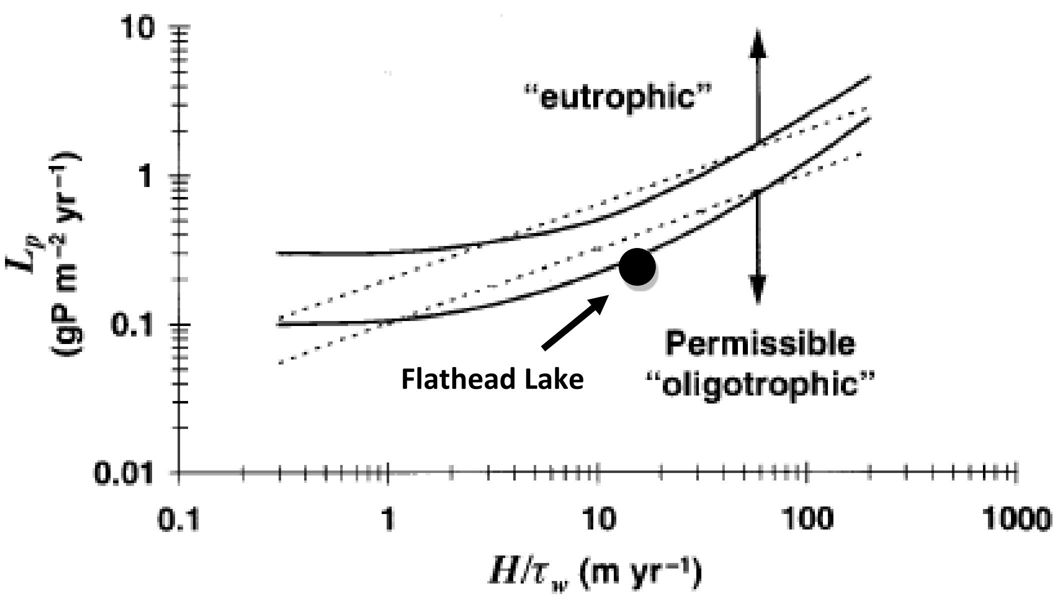

Figure 1. Vollenweider (1975) P-Loading Model, showing Flathead Lake's Position (black dot). The lower solid black line (curved) is the oligotrophic-mesotrophic boundary. The figure (not including the Flathead Lake data) is from Chapra (1997).

[3] Annual P load was calculated from Figure 15 of the document. The load is only comprised of the bioavailable P fraction. The authors report that 90% of the TP load during high-flow events is not bioavailable. Thus, the TP loads associated with high-flow events were already reduced by 90% prior to compiling each annual load.

In recent years there has been much interest in the long-term effect of the *Mysis* shrimp invasion on the ecology of the lake. A study shows that the lake's PP took a significant step increase around the time the shrimp established itself in the mid to late 1980s (Ellis et al., 2011). The Department understands that there is concern that the proposed TN and TP standards may no longer be appropriate because the fundamental nutrient-Chl*a*-PP relationship has changed. What this concern really boils down to is whether the lake's PP is mainly driven by "bottom-up" factors (i.e., nutrients from the watershed) or "top-down" factors (i.e., in-lake biological influences such as zooplankton grazing rates on phytoplankton). Earlier work (Dodds et al. 1989; Stanford et al., 1997; Spencer and Ellis, 1998) suggest that bottom-up factors were of greatest importance; indeed, a relationship ($r^2 = 0.6$, $p=0.04$) between watershed P load to the lake and PP was found in the post-*mysis* period (1989-1995; Stanford et al., 1997). However, more recent work posits that the altered food web dynamics may reduce the impact of increased nitrogen concentrations (Ellis et al., 2011).

Even if it results that top-down factors are of greater importance in controlling Flathead Lake's PP today than in the past, the proposed nutrient standards should still be valid. They reflect the long-term condition of the lake as we understand it and link clearly to beneficial uses, and my analyses (using well-known nutrient-Chl*a* relationships developed from hundreds of northern temperate lakes) indicate the proposed phosphorus and nitrogen standards align well with the proposed Chl*a* and clarity standards. Even if it were true that Flathead Lake could assimilate—without undesirable water quality changes—higher nutrients than the proposed standards, a more relaxed TP standard of, say, 10 µg TP/L would likely result in a doubling of Chl*a* concentrations, which would cause an unacceptable loss of water clarity (on the order of meters) and a substantial movement towards mesotrophy. Flathead Lake's position near the oligotrophic-mesotrophic boundary in the Vollenweider model (**Figure 1**) lends support to this contention. In short, there is simply too much established limnological work on nutrient-Chl*a* relationships, in hundreds of northern temperate lakes, to suggest that more accurate standards to protect Flathead Lake's water clarity would be dramatically different from what are currently being proposed in Department Circular DEQ-12A.

3. References

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Appendix A. Members of the Flathead TMDL Team and their Affiliation, as of January 23, 1995.

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